Mariculture in the Boka Kotorska Bay: Tradition, Current State and Perspective

Milica Mandić, Zdravko Ikica, and Slađana Gvozdenović

Abstract This paper presents data on initial scientific research activities conducted in order to explore the possibilities for bivalve farming in the conditions of the Boka Kotorska Bay; the data on experimental project related to technology transfer and protection of farming sites against predators, as well as the methods for defining the mariculture sites and principles that sustainable bivalve and fish farming should be based on. Mariculture development in Montenegro began after the completion of initial explorations on the possibilities of farming edible bivalves on the area of the Boka Kotorska Bay, which were conducted in the 1960s. After this period, the first commercial farming of mussels (*Mytilus galloprovincialis*) began, while the first commercial farming of oysters (*Ostrea edulis*) began in 2009 in the Bay of Kotor. Today, there are around 20 active shell farms as well as two fish farms using the multitrophic aquaculture system. Bivalve farming is done using the traditional method of floating parks system (long-lines), while fish farming is done in floating cages.

Keywords Boka Kotorska Bay, Farming technology, Mariculture, South Adriatic

Contents

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1 Introduction

Aquaculture is a dynamic industry with annual growth rate of around 10.8%, with a high profit rate, particularly in developed countries [1]. World mariculture production (18.3 million tonnes) comprises marine molluscs (75.5%, 13.9 million tonnes), finfishes (18.7%, 3.4 million tonnes), marine crustaceans (3.8%, 3.9 million tonnes) and other aquatic animals (2.1%, 0.33 million tonnes). The share of molluscs (mostly bivalves, e.g. oysters, mussels, clams, cockles, ark-shells and scallops) declined from 84.6% in 1990 to 75.5% in 2010, reflecting the rapid growth in finfish culture in marine water, which grew at an average annual rate of 9.3% from 1990 to 2010 (seven times faster than the rate for molluscs) [1]. World per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (preliminary estimate). World food fish aquaculture production expanded at an average annual rate of 6.2% in the period 2000–2012 (9.5% in 1990–2000) from 32.4 million to 66.6 million tonnes [2].

According to Information System for the Promotion of Aquaculture in the Mediterranean (FAO-SIPAM) for 2012, total marine and brackish water aquaculture production in the General Fisheries Commission of Mediterranean (GFCM) areas (excluding aquatic plants, freshwater aquaculture and marine and brackish aquaculture from Atlantic areas) increased from about 540,000 tonnes in 1990 to around 1,400,000 tonnes in 2010 [3]. These data indicates a huge demand for aquaculture products and the high rate of development of this sector.

Taking into account the intensive growth of the human population worldwide and that food availability in many countries is decreasing, it is necessary to intensify the production of healthy food in existing areas and also to identify additional locations. Experiences of many coastal countries in the process of production of healthy food in the sea resulted in the fact that mariculture today is a strategic development industry. Mariculture provides opportunity for producing protein rich food and economic development of the area in which the farming activity is done. Considering that development of this sector in the Boka Kotorska Bay is limited in terms of development of industrial production in mariculture, potential threats to marine and coastal diversity of species are negligible.

Although the Fishery Strategy of Montenegro 2015–2020 provides for an increase in production of autochthonous species, particularly as regards bivalves, the production growth is still limited, considering the natural potential, but long-term prospects are quite good. Over the past few years, the global production in aquaculture has been increased and reached a point above 50% of commercial fish catch in fishery [4]. Farming of fish and other marine organisms in Montenegro is done on the basis of the following: the Law on Marine Fishery and Mariculture [5], the Spatial Plan for Special Purpose Area for the Coastal Zone [6], the Law on Environment [7], the Law on Environmental Impact Assessment [8], the Law on Nature Protection [9] and secondary legislation applicable based on the abovementioned laws.

2 History of Mariculture in Montenegro

Initial exploration on the possibility of mussel (*Mytilus galloprovincialis*) and oyster (*Ostrea edulis*) farming in Boka Kotorska Bay goes back to the early 1960s of the last century. Farming process implied three stages of cultivation for oysters and two phases of mussels farming. Bundles of branch, the so-called fašine, were placed in the sea, and young oysters were caught on them after 6 months. Then oyster fries were extracted from the sea for second phase. Second phase implied processing and beam forming braids with diluted branches. The third phase involved the removal of branches, cementing and interference in the final braids.

Mussel farming was somewhat easier compared to oyster farming, and it implied two stages – collecting young on old ropes, the so-called kadena that were placed horizontally below the surface. Collecting the fries was followed by a second phase – the removal of young mussels from *kadena* and involvement in braids, which have been positioned on the floating park in the space of 35–40 cm. Breeding parks and piers were a steel structure, and these experimental parks were placed in positions with a very shallow depth (5–10 m).

Total time of oysters growing lasted from 28 to 30 months, while mussel reaching market size in 2–3 years, depending on the size of the individual [10].

Farming technology had involved stationary parks for mussels and oysters (Fig. 1), as well as oyster cementing using a methodology similar to that still

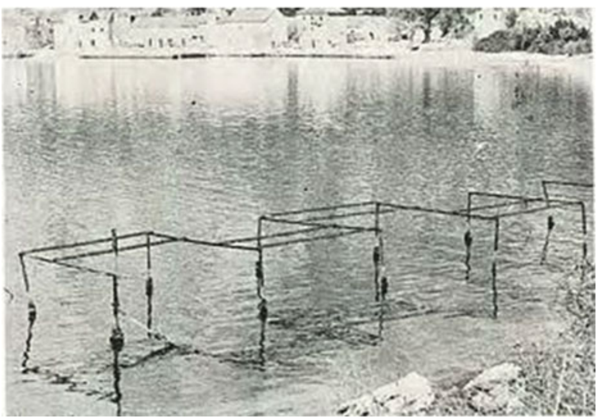

Fig. 1 Former appearance of the experimental stationary park (Orahovac, Montenegro) [10]

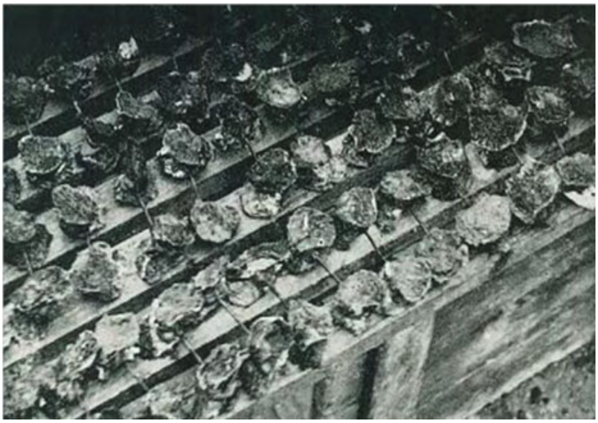

Fig. 2 Oyster cementing method in the first investigations on possibility for farming in the Boka Kotorska Bay [10]

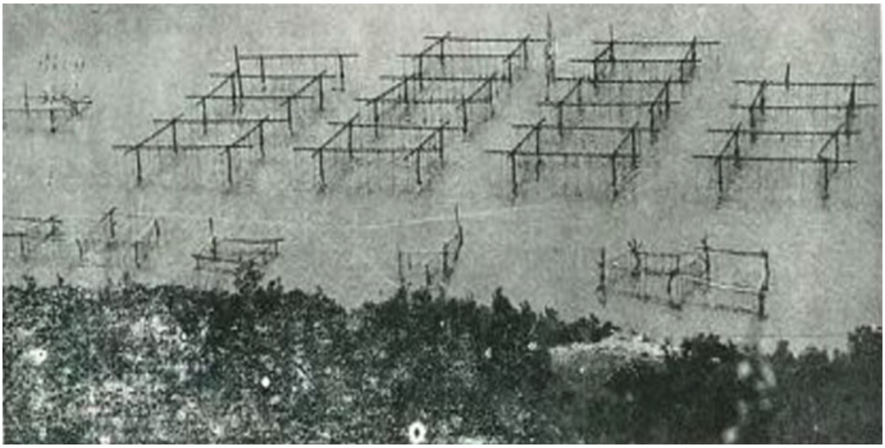

Fig. 3 Former appearance of the stationary park for oyster and mussel farming, the Malostonski Bay, Croatia [10]

used in most of Adriatic and Mediterranean countries (Fig. 2). Former appearance of stationary parks in countries of the region is presented in Figs. 3 and 4.

Several decades after the initial surveys, commercial mussel farming on the area of the Boka Kotorska Bay began to develop in the second half of the 1980s and it implied introduction of the floating parks methodology, used even today, while commercial oyster farming began as late as in 2009. Today, the farming technology of mussels and oysters in the Boka Kotorska Bay uses long-lines system, which proved that it meets all the necessary conditions for safe production [11].

In the period of the first surveys until today, additional research activities and experiments have been made in order to explore the possibilities for the Pacific oyster (*Crassostrea gigas*) and rainbow trout (*Oncorhynchus mykiss*) farming in the

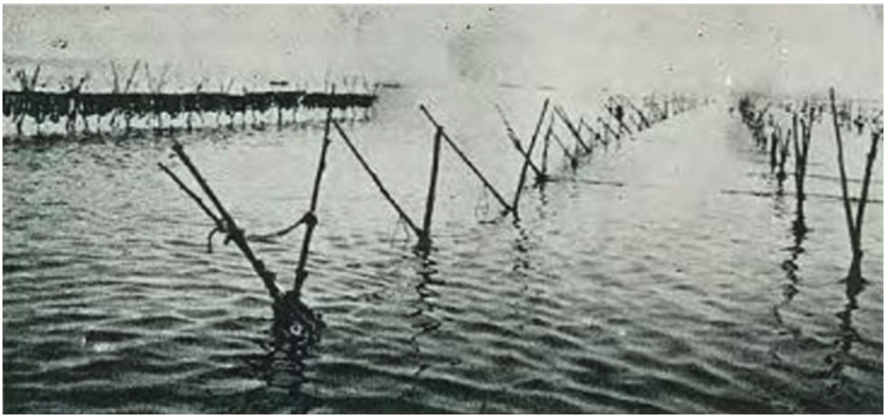

Fig. 4 Former appearance of the stationary park for *M. galloprovincialis* farming, the Taranto Bay, Italy [10]

sea. One of the very important segments of marine aquaculture is technology transfer, and in that regard activities were conducted with colleagues from Spain, Italy, Norway and China. Many plans such as farming of salmon, brine shrimps *Artemia salina*, eel (*Anguilla anguilla*), mullet (Mugil sp.) as well as development of lagoon farming are still in the conceptual phase as a result of lack of funds.

3 Current State of Montenegrin Marine Aquaculture: Species, Technologies and Production

Marine aquaculture in Montenegro includes fish farming (sea bass and sea bream) and farming of two species of bivalves – mussels (*Mytilus galloprovincialis*) and oysters (*Ostrea edulis*) (Fig. 5).

Bivalve farming is at a relatively low level, considering the natural potential available. In 20 farming sites on the territory of the Boka Kotorska Bay, the current annual mussel production is somewhat below 200 tonnes [12] (Fig. 6), while the quantity of oyster farmed is negligibly low, considering that the first farming site was set up in 2009 (Fig. 7). Sale is done mainly through direct supply, while lately retail chains have begun placing this product on the market. One of the major problems in this sector is absence of a centre for dispatch and depuration of live molluscs (absence of sanitary-hygiene conditions necessary for exports) as well as lack of organized market.

White fish farming implies a closed farming cycle in floating cages in the sea. Although it shows a mild growth over the past few years, it is still at a low level, particularly in comparison with countries with relatively small production (Croatia, Albania, Morocco or Tunisia). Two fish farming sites on the territory of the Boka Kotorska Bay have annual production of around 120 tonnes [12]. Production shows

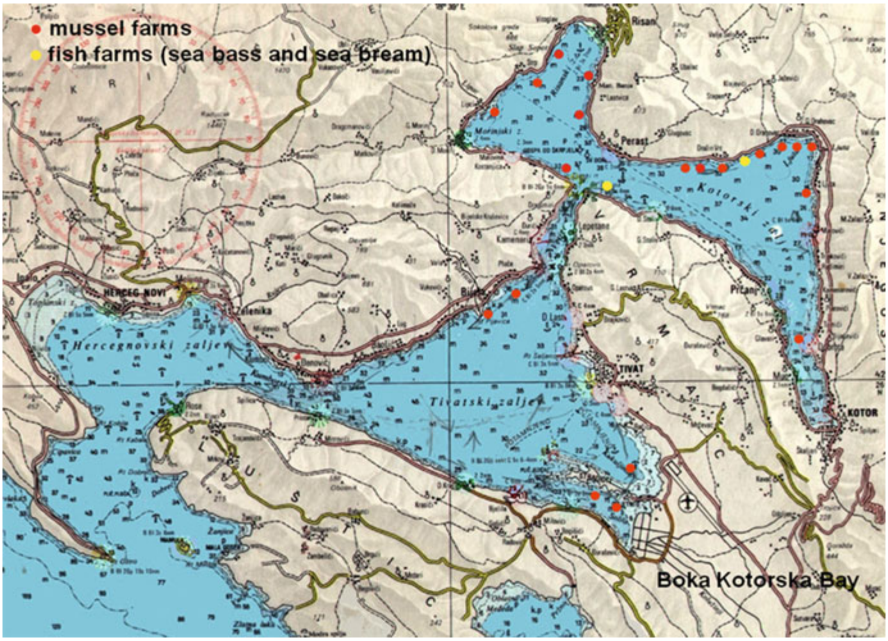

Fig. 5 Map of bivalves and fish farming sites (the Boka Kotorska Bay)

Fig. 6 Technology of mussel farming in Montenegro

Fig. 7 Technology of oyster farming in Montenegro

growth in recent years, thanks to decisive management of one of the two existing farms. However, the development of this sector is stagnant, as there are no defined locations for aquaculture in the open sea of the Montenegrin coast, which should be an integral part of the spatial plan of the coastal zone management and which should constitute security for investors to invest in cage farming. There is a growing interest in recent years by various investors for growing not only sea bass and sea bream, but also for Atlantic bluefin tuna (*Thunnus thynnus*). Poor development of aquaculture in Montenegro contributes to the conflict of this sector with tourism and ecology, and ignorance of the actual situation and the possibility of linking these sectors. Although fish farming can significantly affect the ecological and biological condition of water, proper and sustainable management of production, regular monitoring of the environment and regular control to prevent the risk and disease could make the development of this sector viable and environmentally sound [13].

Fish farming has a negative impact on the environment, it can generate considerable amounts of effluent, such as waste feed, faeces, medicinal substances, heavy metals and persistent organic pollutants, which can pollute the marine environment with a range of negative impacts varying in severity [14–18]. Unlike extensive aquaculture of mussels and oysters, which uses primary production from the marine ecosystem, intensive production of fish within sea-cages is increasingly occupying more coastal space, uses high protein pellets for feeding and introduces a large source of nutrients to coastal areas which can exceed the assimilative capacity of the local marine environment, leading to coastal eutrophication [15, 16]. Development of fish farming in the open sea (semi-off shore and off shore aquaculture), intensive control of the fish stocking density in order to overcome possibility of overcrowded conditions and consequently possible development of diseases, polyculture production systems (IMTA), combining the cage system with an artificial reef [19] are just some of the solutions for overcoming the negative impact of fish farming.

During several years of research activities conducted in cooperation with bivalve farmers, a number of important projects have been implemented of which we would like to highlight the following: (1) technology transfer aimed at increasing the mussel production on the territory of the Boka Kotorska Bay, and (2) protection of farming sites against predatory fish species.

The first project implied introduction of the technology of the so-called shark ropes, intensively used in Spain (Galicia) in raft systems. Juvenile mussel attaching was done by hand on ropes 12 m in length, put in a 'U' position on existing long-line systems. In 2 farming sites included in the experiment attaching was done on 3 ropes each, with different juveniles density (400, 500 and 600 g/m). Juveniles were attached using a cotton biodegradable net (Fig. 8). Upon regular monthly monitoring, it was established that mussel growth is extremely good, but that the said technology cannot be used on long-line systems due to the weight that raft system supports relatively easily. Nevertheless, in this experiment it was also

Fig. 8 'Shark rope' prepared with juvenile mussels colony

established that the said ropes are extremely favourable as spat collectors if placed horizontally, at the depth of about 1 m, which is the way in which the farming sites that participated in the experiment are using them currently.

The second project was an attempt to resolve the problem of mussel and oyster predators in farming sites. The predation issue in farming sites is an issue spread throughout the Mediterranean [20–24]. The experiment implied placing of three different types of protective nets in three sites in the Boka Kotorska Bay. The first net type (Fig. 9) was designed in cooperation with farmers. Net mesh size is 50 × 50 mm, they are hand-made nets, made of polyethylene based on experiences of our farmers and in cooperation with the scientific staff of the Institute of Marine Biology. The number of nets placed in all 3 sites was 300 each.

The second net type, the so-called Spanish nets with mesh size 15 × 15 mm, is made of polyethylene and they are extremely strong. The manufacturer is company JJChicolino (Spain) and the nets were reinforced with plastic hoops prior to their placing into the sea (Fig. 10a, b).

The third net type is also made of polyethylene (Fig. 11) with mesh size of 50 × 50 mm, but is far stronger than the first two type nets. The manufacturer is company Sigma Promet from Bečej (Serbia). After preparation and treatment of protective nets, supplied in rolls 1.2 m in width and 25 m in length, the nets were distributed to farming sites.

Upon completion of a thorough analysis and monitoring of the quality, strength and resilience of the nets that lasted for several months, it was concluded that two net types (type 2 and type 3) can be widely used to protect farming sites against

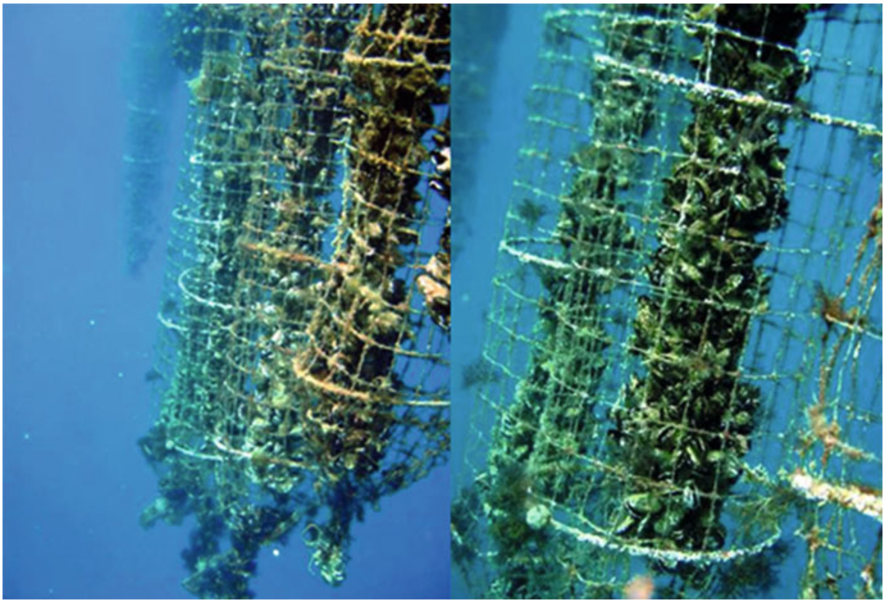

Fig. 9 The first type of protective nets placed on *pergolar* – mesh sleeves

Fig. 10 Spanish net reinforced by plastic hoops (**a**) and difference between type 1 and type 2 nets (**b**)

predator fish species. The first net type was not of a satisfactory quality in terms of resilience and net strength, so we do not recommend it to farmers to protect their farming sites. The net types 2 and 3 were of considerable quality in terms of strength, resilience and protection of the farming site; however, we note that type 2 net has much smaller mesh size so the quantity and intensity of fouling organisms is much higher than in the type 3 net, which causes additional burden to farmers. The results of this project found a direct and wide use among bivalve farmers who are intensively using the recommended net types, while results were officially supported by the Ministry of Agriculture and Rural Development of Montenegro.

Fig. 11 The third type of protective nets

4 Problems and Possible Threats in Mariculture Development

One of the main reasons due to which this sector is not sufficiently developed is absence of new farming sites, particularly in the open sea. Spatial planning plays a major role in resolving this key problem, in the process of site selection not only in order to resolve possible conflicts with other activities in the sea (tourism, transport, navigation and fishing) but also in order to ensure security to investors.

The additional problems are related to fouling organisms, predatory fish species, presence of unregistered farming sites, absence of organized market, absence of dispatch centre and an active depuration centre, as well as unused opportunities for farming other autochthonous bivalve species attractive for the market.

The major threats are possible faecal pollutions and biotoxins that many countries in the region have been facing.

5 Prospects of Mariculture Sector Development in Montenegro

Advancement and technological development of the mariculture sector should be based on security standards and preservation, development and promotion of quality food from the sea, in accordance with contemporary production and market trends, along with preservation of natural values of the area concerned. In future development activities, this sector should be taken into consideration through its multi-functional link with tourism. There are numerous development opportunities for cooperation of the two sectors (gastronomic contribution to the tourist offer, increase in national consumption of healthy food from the sea, reduction of fishing pressure on existing resources and creation of new jobs).

On the basis of previous studies conducted by the Institute of Marine Biology, potential locations for aquaculture in the open part of the Montenegrin coast have been proposed [13].

The sites proposed are stated as potentially suitable for mariculture program, which means that it is necessary to conduct baseline surveys for each site separately. The criteria listed are laid down in accordance with the FAO AZA concept (Allocated Zones for Aquaculture) – a concept based on which locations suitable for mariculture are identified. This concept is proposed by the General Fisheries Commission for the Mediterranean (GFCM) that Montenegro is a member of, and it implies the observance of the ICZM Protocol, the ecosystem approach to aquaculture development, the Blue Growth as well as observance of three fundamental principles, as follows:

1. Aquaculture development and management should take into account the full scope of ecosystem services without jeopardizing their sustainability,
2. Aquaculture development enhances human wellbeing and the principle of equality for all relevant users,
3. Aquaculture development has to be developed in accordance with development of other sectors, policies and objectives,

all that in accordance with the Directive 2014/89/EU. Baseline surveys entail the following analyses:

Basic information:

– Bathymetry analyses (minimum sea depth depends on the species of the organism farmed – bivalves or fish),
– Coastal infrastructure and accessibility of the location,
– Basic infrastructure: availability of roads and communication, availability of electric power and vicinity of ports.

Administrative information:

– Protected areas (natural parks, RAMSAR sites and sites of particular importance),
– Waste disposal sites (landfill),
– Submarine cables,
– Tourist areas (beaches),
– Submarine archaeological areas,
– Traditional fishing zones,
– Fishermen’s posts,
– Artificial reefs, and

– Military zones.

Environmental information (biophysical characteristics):

– Climatology (temperature, winds, precipitation and evaporation),
– Site exposure to the open sea,
– Seabed characteristics (sediment structure – granulometry, organic matter, demersal ichthyofauna, phyto- and zoobenthos),
– Water quality (oxygen, salinity, chlorophyll a, temperature, suspended matter, water transparency and nutrients),
– Trophic status (oligotrophic, mesotrophic and eutrophic),
– Organographic conditions (waves – minimum and maximum amplitudes, sea currents – course and direction, hydrodynamics),
– Sanitary quality (microbiology).

With a view to sustainable development of the sector, opportunities for appropriate monitoring of the environment in all phases, introduction of the indicator system [25] and the above-mentioned AZA concept is proposed in order to avoid some impacts of aquaculture by improving the site selection process and, in turn, protecting aquaculture itself from adverse environmental conditions. This would also likely prevent conflicts among stakeholders on the use of the marine resources by enhancing the integration of aquaculture with other activities within the coastal areas [25].

6 Conclusions

Mariculture development in Montenegro is at a relatively low level compared to the opportunities offered by the area of the Boka Kotorska Bay and the open sea of the Montenegrin coast. All the sites where mariculture takes place are located in the area of the Boka Kotorska Bay, while the open sea is still completely unused for mariculture program. Furthermore, introduction of new autochthonous fish and bivalve species, transfer of technologies, experiences and know-how, development of organic farming, insisting on multitrophic aquaculture as well as stronger support to the research and development sectors are doubtlessly the directions in which the sector should be developed further. Not only in Montenegro, but also Mediterranean aquaculture is still at an early stage of development although some productions (molluscs) have already a long tradition. Its sustainable development needs a better integration in the society and to take better into consideration basic principles. At the international/regional level there is a current effort to streamline the sector, its framework and its communication tools (European Federation of Aquaculture Producers, Committee on Aquaculture of the General Fisheries Commission for the Mediterranean). However, as in many other cases, the Mediterranean aquaculture is quite diverse in terms of stage of development and needs for scientific and technological support. The current efforts made by various international entities should be better coordinated and strengthened. However, the efforts are also to be made at the local levels where operational decisions are to be made and the development is to take place [26]. Taking into account that accession to the European Union is Montenegro's strategic objective, it also implies adoption and implementation of ecological and technological standards of the Union. It is beyond doubt that apart from economic development, development of tourism and services, mariculture, along with fisheries, will become one of the most important development sectors, taking into account the fact that global demand for healthy food produced in the sea is at a high level.

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